Chapter 3: Watershed Hydrology
Appendix 3.G: St. Johns River Watershed Water Supply Impact Study Model Review by INTERA

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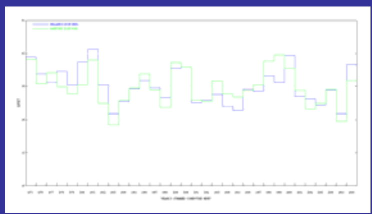
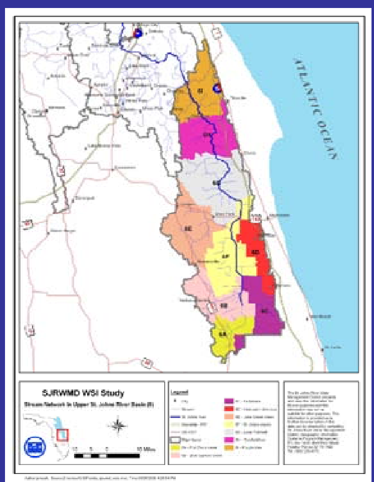
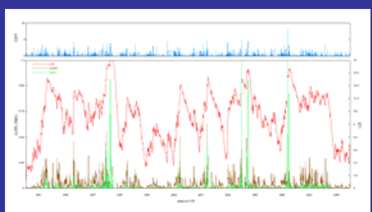
St Johns River Watershed Water Supply Impact Study Model Review







Prepared for:

The St. Johns River Water Management District

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Introduction

The St Johns River Water Supply Impact Study (WSIS) was performed to analyze the potential environmental impacts to the St Johns River due to surface water withdrawals. With this goal in mind, the watershed hydrology component of the WSIS was reviewed to assure the watershed hydrology model was conceptualized, constructed, and calibrated using current and proper engineering practices.

In the review process, emphasis was placed on the replication of the water balance. The water budget is the dominant component of the watershed hydrology model and alternative comparison. The determination of the water balance is dependant on the conceptualization.

HSPF Introduction

The Hydrologic Simulation Program—FORTRAN or HSPF is a comprehensive hydrologic model. The model is used to simulate the hydrologic water balance of regional watersheds. The model has been applied for use in the evaluation of water supply impacts, minimum flows and levels, pollution load reduction goals, and total maximum daily loads. The HSPF model has been successfully applied to many watersheds in the state of Florida. It can properly represent the hydrologic response from pervious basins, impervious basins, and routing reaches. It has the capability to simulate a wide variety of conditions.

Model Conceptualization

The conceptualization of the watershed hydrology component of the WSIS was reviewed to assure the model represents the basin in a manner that maintains the mass balance of the watershed as well as maintaining a correct representation of the physical processes.

Model Discretization

Model discretization is the process in which the landscape of the model domain is divided into discrete parts. This is typically the first part of constructing a numerical representation of the model domain. The discretization uses the basic building blocks of the hydrologic model in the conceptual design of the model. In the case of HSPF the basic building blocks are pervious land segments (PERLND), impervious land segments (IMPLND), and reach reservoirs (RCHRES).

Time Discretization

The time step used in the St Johns River WSIS is 1.0 hour. Many of the HSPF parameters are sensitive to the time step. This means the predictive models must use the same time step as the calibration. There also must be an understanding that the model may not perform well for rain events with extreme rainfall intensities. HSPF simulates infiltration excess runoff. This means runoff is generated when the rainfall intensity exceeds the infiltration capacity. Intense rain events typically are short in duration (and also small scale; see rainfall section below). Long time steps in the model tend to average down these intensities. The model calibration will shoot through the middle of the high intensity and low intensity events. However, the time step was defined by the best available rainfall data for the long term simulations. Therefore, the model time step and the calibration represent the best available results which follow current engineering practices.

Land Use HRU

Sub-dividing the basins into Hydrologic Response Units (HRU) is the best conceptualization for a hydrologic model. The watershed hydrology model utilized the HRU approach in the model conceptualization. The watershed hydrology model started with the hydrologic basin boundaries. These boundaries were developed using topographic divides. Maintaining the basin boundaries is critical in the numerical representation in the model construction; the area that contributes to a particular flow station needs to be preserved. Preserving the contributing area is essential to numerically mimic the water balance of the basin. In the watershed hydrology model models, the basins were then sub-divided into the HRU using the land use mapping. Using the intersection of basins and land use allows the model to preserve the basin area while maintaining similarity in the hydrologic processes and therefore the basin parameters. Lumping areas of like land use prevents the aggregation of dissimilar hydrologic properties. When starkly different hydrologic conditions are aggregated, the hydrologic response of the model is dramatically impacted. The aggregated parameters must be averaged, causing the model to respond with average results. The watershed hydrology model followed proper technique and current engineering practices in the conceptualization of the land segments.

Developed Lands – Pervious and Impervious Fractions

It is common practice in HSPF to simulate developed lands with two segments: Pervious Land Segments and Impervious Land Segments. Using this technique prevents the lumping of starkly different conditions. By definition, impervious land segments do not have infiltration, while pervious land segments have infiltration losses as well and soil based storages. The SJR watershed hydrology model followed this common practice.

Unfortunately, calibration is usually done at the basin level since data supporting individual parameter adjustment of the pervious and impervious fractions is rarely available. Given the lack of individual calibration, there is uncertainty as to the degree the impervious fractions provide water to the basin outfall. In addition to this uncertainty, most of the impervious runoff enters wetlands (whether man made or natural) that tend to attenuate the surface flux. Care must be taken when extrapolating the calibrated parameters to the future land use conditions.

Given the uncertainty in the calibration, especially the relative contribution of the pervious and impervious land segments, caution should be used in predicting the contributions of future land use. This would be especially true given large swings in impervious land use. For example, if the relative contribution of the impervious land segment were erroneously high by a small (for the case of the argument un-noticeable) fraction, as the basin becomes more and more developed, it would exaggerate the error. Exaggerating a small error when up-scaling to the future land use condition would erroneously allow the model to simulate more water is available.

DCIA and Land Use Classification

Percent impervious area and directly connected impervious area (DCIA) used by the HSPF models are shown in Table 1. Industrial and commercial land use includes a large number of categories, including airports, water use plants, paper mills, cemeteries, military, and governmental land uses. For many of these land uses, using a DCIA of 80 percent is extremely high. Extreme care should be taken when selecting the appropriate DCIA percentage for a given land use, particularly in the context of this simulation. The development of the watershed hydrology model models is focused on estimating discharges based on 1995 land use and proposed 2030 land use. The acreages of the PERLNDs and IMPLNDs for the four urbanized land uses noted in Table 2 were determined based on the DCIA values. Not all sub-watersheds used the percentages in this table. It seems the ratio of imperviousness was used as a calibration parameter. Justification would be required if the ratio varied dramatically across the watershed hydrology domain (see following paragraphs).

Large DCIA percentages will result in large IMPLND areas. Relatively, most runoff is generated from these IMPLND areas as compared to the pervious areas. An error in the percent impervious will be a direct error in the simulated runoff. Table 3 shows DCIA percentages used by the District for a SSARR model of Lake Hiawassee (Robison 2008). As shown in the table, the DCIAs for residential land uses are similar to those utilized by the HSPF models. There is a large difference, however, in the DCIA values used for the watershed hydrology model industrial and commercial classification and the SSARR oil and gas storage and industrial classifications (which are both classified by watershed hydrology model as industrial and commercial). DCIA is a source of model uncertainty, particularly given the context of the intended use of the models. In order to quantify this uncertainty, an uncertainty analysis could be conducted using a range of DCIA values for each land use. Several model simulations could be run with different combinations of DCIA in order to assess the differences in discharge resulting from the use of different DCIAs. Performing an uncertainty analysis on one or two sub-basin models would reveal how sensitive the model is to changes in the PERLND and IMPLND areas. This would, in turn, give more confidence in the predictive nature of the model for the 2030 simulation and could also lead to improved calibration.

Table 1. Percent Impervious and DCIA (Source: Volume 1)

	Percent Impervious (%)	DCIA (%)
Low Density Residential	15	10
Medium Density Residential	35	25
High Density Residential	83	65
Industrial and Commercial	90	80

Table 2. Land Use Areas, 1995 and 2030

	1995		2030			1995		2030	
Land Use	**Acres**	**Percent Area**	**Land Use**	**Percent Area**	**DCIA**	**IMPLND**	**PERLND**	**IMPLND**	**PERLND**
1	208124	4.62	706598	15.69	10	20812.4	187311.6	70659.8	635938.2
2	193584	4.30	430890	9.57	25	48396	145188	107722.5	323167.5
3	72657	1.61	155357	3.45	65	47227.05	25429.95	100982.05	54374.95
4	122152	2.71	267510	5.94	80	97721.6	24430.4	214008	53502
5	16940	0.38	12383	0.27	0	0	16940	0	12383
6	89124	1.98	54600	1.21	0	0	89124	0	54600
7	439980	9.77	329657	7.32	0	0	439980	0	329657
8	226976	5.04	145428	3.23	0	0	226976	0	145428
9	114684	2.55	70187	1.56	0	0	114684	0	70187
10	224890	4.99	139990	3.11	0	0	224890	0	139990
11	1248593	27.72	883127	19.61	0	0	1248593	0	883127
12	300380	6.67	300332	6.67	0	0	300380	0	300332
13	1222185	27.14	988296	21.94	0	0	1222185	0	988296
14	23522	0.52	19431	0.43	0	0	23522	0	19431
Total	4503791	100.00	4503786	100		214157.05	4289634	493372.35	4010413.65
				Percent of Area		4.76	95.24	10.95	89.05

Table 3. Land Use and DCIA for District Lake Hiawassee SSARR Model (Source: Robison, 2008).

Code	Land Use	Area [ac]	DCIA	Imp. Area [ac]
1100	Residential, low density - less than 2 dwelling units/ acre	10.3	0.10	1.0
1200	Residential, medium density - 2-5 dwelling units/ acre	0.9	0.23	0.2
1300	Residential, high density - 6 or more dwelling units/ acre	31.1	0.65	20.2
1460	Oil & gas storage (except areas assoc. with industrial)	2.3	0.23	0.5
1700	Institutional	8.2	0.65	5.3
1900	Open land	4.3	0.00	0.0
2210	Citrus groves	6.9	0.00	0.0
5200	Lakes	37.2	0.00	0.0
5340	Reservoirs less than 10 acres	3.9	0.00	0.0
6460	Mixed scrub-shrub wetland	4.7	0.00	0.0
7430	Spoil areas	0.3	0.00	0.0
—	**Total basin [ac]**	**110.2**	—	**27.3**
—	**Total basin [sq. mi.]**	**0.17**	—	**0.04**
—	**Main lake [ac]**	**41.9**	—	—
—	**Total drainage area [ac]**	**68.3**	—	—
—	**Total drainage area [sq. mi.]**	**0.11**	—	—
—	**Impervious area [sq. mi.]**	**0.04**	—	—
—	**Pervious area [sq. mi.]**	**0.06**	—	—

After brief discussions with the District, it was noted that the DCIA reported in Volume 1 of the watershed hydrology model documentation (as shown in Tables 1 and 2), was not consistently used for each model. For some models, DCIA was utilized as a calibration parameter. For the Little Hatchet Creek model, the DCIA as stated in the UCI was as follows: low-density residential, 7.5%; medium and high density residential, 30%; industrial/commercial, 50% (Alley and Veenhuis, 1983). This point should be clarified in the model documentation. When specific models utilize different DCIA percentages, the DCIA percentages should be correctly specified in the documentation. The DCIA values used by the Little Hatchet Creek model are more within the range of commonly utilized values. The DCIA ratios in the original manual are high and will result in generating water when land is developed (i.e., future case).

Future Land Use

Based on a comparison of the 2030 simulations with the calibration simulation, it is evident that the models are highly sensitive to changes in land use (specifically the DCIA as discussed above). Combined with high DCIA values for some land uses, changes in land use result in increased impervious areas and associated increases in runoff, and therefore, discharge. A summary of the 1995 and 2030 land use is shown in Table 4. As shown in the table, some land uses, particularly land uses with impervious segments (land uses 1 through 4) experience large increases in area between 1995 and 2030. Of concern in the table is the decrease in wetland area of approximately 19.1%. Wetland area (as well as water) should remain the same (or almost the same) between 1995 and 2030 due to required mitigation. Thus, there is some uncertainty associated with the land use utilized to develop the 2030 simulation. The reduction of wetland and lake area is against the report provided by GIS Associates where it states (GISA, 2009):

> 9) Undeveloped land uses (excluding water and wetlands) were reduced to offset the increase in industrial and commercial acreage by watershed. This reduction for each use was made in proportion to its reduction due to projected residential uses.

Table 4. 1995 and 2030 Land Use (Source: Volume 1)

	1995 Land Use (acres)		2030 Land Use (acres)	
1. Low Density Residential	208124	4.62%	706598	15.69%
2. Medium Density Residential	193584	4.30%	430890	9.57%
3. High Density Residential	72657	1.61%	155357	3.45%
4. Industrial and Commercial	122152	2.71%	267510	5.94%
5. Mining	16940	0.38%	12383	0.27%
6. Open and Barren Land	89124	1.98%	54600	1.21%
7. Pasture	439980	9.77%	329657	7.32%
8. Agriculture General	226976	5.04%	145428	3.23%
9. Agriculture Tree Crops	114684	2.55%	70187	1.56%
10. Rangeland	224890	4.99%	139990	3.11%
11. Forest	1248593	27.72%	883127	19.61%
12. Water	300380	6.67%	300332	6.67%
13. Wetlands	1222185	27.14%	988296	21.94%
14. Forest Regeneration	23522	0.52%	19431	0.43%

Wetlands and Open Water

The watershed hydrology model conceptualized isolated wetlands and open water land forms using the HSPF Pervious Land (PERLND) module. This is technique is not outside accepted practices, but care must be taken to adjust model parameters to obtain an accurate predictive tool. The parameters of the PERLND module will need to be adjusted to mimic the processes present in the natural system. The major parameters or simulated water balance terms of critical concern include actual ET, infiltration, storage, discharge and inflows. The processes are interrelated which make model calibration with PERLNDs difficult.

Wetland ET rates are very close to potential ET rates. Wetlands have the capability to store large quantities of water. Surface storage of most wetlands are on the order of several feet. This storage allows the wetlands to maintain actual ET rates long after precipitation events. In addition to surface storage, there is a large storage potential in the wetland soils, which are typically high organic content. Only under severe drought conditions do the wetlands show signs of wilting or limited available moisture.

In the St Johns watershed hydrology model an attempt to increase the storage capacity of lakes and wetlands represented as pervious land segments was made. Upper zone storage capacity was increased to achieve the increased storage present in the physical landscape. Unfortunately, the increased storage capacity of the UZS does not represent the 2-3 feet present in many of the wetlands. Although other storages in the pervious land segment are available to represent the total storage capacity of the lakes and wetlands they will rarely achieve the 2-3 feet storage capacity. The lack of storage will be reflected in reduced AET rates from the model as the reduced storage will limit the available water to satisfy PET.

True infiltration in wetlands and lakes can be very small. Some wetlands and lakes are Surficial and Floridan aquifer discharge zones. However the HSPF model can utilize infiltration as a means to access lower storages. Lower zone storage (LZS) and active groundwater storage (AGWS) can be utilized to help mimic the storage capacity of the wetland or lake. Accessing these lower storages will allow the potential ET to be met without limiting the available moisture. In order to mimic the ET from these storages the lower zone ET parameter (LZETP) and the active groundwater ET parameter (AGWETP) will need to be adjusted to allow increased ET from these storages.

The wetland or lake discharges are typically controlled by the geometry of the outlet. It would be a daunting task to measure the specific geometry of each outlet control for every wetland and lake. The idea is to mimic the storage and attenuated outfall from these hydrographic features. In HSPF, only the slope, hydraulic length, and Manning's 'n' control the discharge from the PERLND module. The surface storage in HSPF quickly returns to zero as it is free to discharge. The inability of HSPF to maintain water on the surface requires an unrealistically large quantity to be infiltrated so as to take advantage of the lower storages (LZS, IFWS, and AGWS). The discharge from the lower storages can be controlled with a single parameter (one for each) and defined as the recession constant. The recession constants will have to be calibrated as to mimic the attenuated discharge from the wetland and lake land forms.

Wetland and lake features of the landscape are typically located in low lying areas. Being in low topographic areas allow the wetlands and lakes to receive surface runoff from the surrounding basin. This inflow to the lakes and wetlands allow additional water to fill storages which in turn will allow the maintenance of the high ET rates. It is this process which will attenuate the overall basin outflow. Currently the St Johns River watershed hydrology model does not route runoff from the uplands into the wetlands and lakes. This prevents two things: 1) the attenuation of the overall basin discharges, and 2) the additional inflows to the lakes and wetlands to help maintain the high actual ET rates.

If the wetlands and lakes represented as pervious land segments comprised of a small fraction of the basin the significance of errors would be small. A review of several UCIs shows that the wetlands and lakes simulated as pervious land segments are, in fact, significant. An evaluation of some of the UCIs showed the lakes and wetlands represented with pervious land segments in the model was as high as 20-25% of the total simulated area. The open water land use was a small component of the landscape but the wetlands were a very significant component.

The vast storage in wetlands as well as the predominance in the Florida landscape makes the wetlands an important feature in controlling the hydrologic response of a watershed. Wetlands tend to act as storage attenuation features of the watershed. The true runoff process occurs very rapidly. Overland flow runoff rapidly leaves the upland landscape and enters the lowland features. The lowlands or wetlands store the runoff and discharge the water over the next few weeks or months. The delayed discharge is storage attenuation where the large storage capacity delays the release of water. This delay allows more time for the stored water to ET to the atmosphere.

Model Boundary Conditions

As with all models, boundary conditions must be defined within HSPF. The most significant model boundary conditions are rainfall and ET. These boundaries are defined with time series which define the boundary condition of the basins which describe the inflow and outflows of the model. Additional boundaries include diversions or discharges from mining or waste water discharges. The additional boundaries are typically small but should be accounted for none-the-less. Descriptions of the significant boundary conditions are found in the following sections.

Rainfall

Precipitation is the largest component of the annual hydrologic budget. There are a variety of difficulties associated with representing the correct spatial and temporal distributions of rainfall within a basin. Precipitation in Florida can generally be classified into two types of events: frontal and convective. Frontal events are typically long lasting and widespread, sometimes covering the entire state. This type of event is commonly associated with cold fronts in the winter season. Frontal storms, due to their size, timing, and relative homogeneity, are simpler to observe and accurately represent in a hydrologic model. Conversely, convective storms (thunderstorms) in Florida are typically 15 miles in diameter, last less than an hour and move anywhere from zero to ten miles in that time, unless they are part of a larger faster-moving system. Spatial and temporal variability of rainfall within the cell can be very high. Tropical storms and mesoscale convective systems have higher spatial extent and can last longer, sometimes producing very large ground accumulations of rainfall. However the temporal and spatial distribution of rainfall within these systems is also high. A convective cell is usually much smaller than a basin, which leads to spatial variability of rainfall within the basin. The high rainfall intensity associated with convective activity makes it impossible to accurately represent these storms with long numerical time steps.

Ideally, rainfall data with good spatial and temporal resolution are available and used in order to accurately simulate infiltration-excess dominated runoff, which is common in

Florida. For this type of runoff to occur, the intensity of the rainfall must exceed the infiltration capacity of the soil. This means that if a large time step (ie. daily or greater) rainfall record is used directly in a hydrologic model, intensities would be small, and the model would rarely produce runoff.

Radar data is an ideal data source for accurate spatial and temporal rainfall distributions and has been used from hydrological applications for almost 40 years. However, due to the fact that archived NEXRAD data prior to 1995 does not exist for this region, it was decided not to use radar data for the models described in this report. This was a sound engineering decision; when a model uses one type of input data for calibration, it is ideal to have the same type of input data for prediction. This ensures that the model is not biased in its predictive capability. As an alternative to the use of NEXRAD data, Thiessen polygons were developed using available rain gauges in or near the St. Johns watershed. Based on the Thiessen polygons, the rain gauge that covered the majority of the sub-watershed was used as an input for that sub-watershed.

As part of this study, daily rainfall was disaggregated into hourly rainfall in order to create a more temporally detailed time series which is necessary to more adequately capture infiltration excess runoff. The procedure developed by the District to create the rainfall input datasets is consistent with common engineering practice and utilized the most complete data sources available. The District should be commended for this rigorous, comprehensive and well-conceived approach for developing hourly rainfall data for the St. Johns watershed. For the purposes of completeness, it would be helpful to add a table to the report documentation listing all gauges used in the input WDM, as well as their source and original time step.

With each sub-watershed relying on the rainfall data from a single rain gauge, this station not always being within the sub-watershed, and not always having hourly data as its raw source, the models cannot be expected to always produce a good fit to observed streamflow for individual events.

The District should consider calibrating the sub-watershed models with the shorter 1995 to present NEXRAD dataset using the same approach and objective functions as described in Volume 1. Comparing the model outputs using the same statistics (Nash-Sutcliffe) would provide the District with an indication of how much the model underperformance is due to issues with the major forcing variable (rainfall) versus uncertainty in model parameters such as vegetative cover and evaporation.

ET

Potential evapotranspiration (PET) is the potential rate at which the atmosphere can uptake water from the watershed hydrology model landscape. The actual evapotranspiration (AET) rate is the rate that water actually leaves the system via the atmosphere. The AET is limited by the available moisture supply and vegetation type of the basin. The available moisture is supplied from the storages within the basin. In the case of water bodies, that remain wet all year, there is no limit of moisture nor limitation due to vegetation. Traditionally, evaporation data is collected via a Class A pan. A pan coefficient (of less than 1.0) is applied to the data in order to account for the factors (such as the heating of the pan and boundary conditions) that cause pan measurements to overestimate ET rates.

Based on an examination of the pan data available throughout the District, it was decided not to utilize the available pan data due to high data variability between pan sites and data gaps in the pan records. Instead, a PET time series was developed using the Hargreaves Method and scaled with a factor calculated using the Penman method. The Hargreaves method calculates daily evaporation using minimum and maximum daily temperature and extraterrestrial radiation.

PET was computed using data from eighteen available meteorological stations in four basins. Theissen polygons were used to assign stations to all subbasins. The station whose Theissen polygon covered the most area in the basin was used for the entire basin. Since PET is less spatially and temporally variable than rainfall, the use of a single station will result in an adequate spatial coverage of the modeled basins.

The calculated PET data was compared to the Geostationary Operational Environmental Satellite (GOES) based PET currently available throughout the state. The Hargreaves PET was generally found to be higher than the GOES PET, and thus, and average correction factor between the two methods was calculated and applied to the Hargreaves ET. In order to more thoroughly examine the final PET rates that were applied to the model, it is recommended that an additional table be added to the report documentation with the final corrected annual PET rates by gauge. This will make it possible to identify any anomalies in the data. Additionally, the methodology on data gap-filling of the meteorological record and the extent to which gap-filling was necessary should be added to the documentation. Based on a review of the documentation and the data, the development of the ET input time series follows standard engineering practices.

Irrigation

Irrigation can be a significant water budget term. The irrigation demand can be a significant stress on the irrigation source. The irrigation process also maintains soil moisture and therefore will increase the simulated ET as well as runoff. Some UCI utilized the irrigation module of HSPF. HSPF irrigation module is a powerful tool to help estimate the impacts of irrigation on the water balance.

Model Construction

After the model is conceptualized, model construction can commence. The construction typically includes the processing of spatial data as well as temporal data. The spatial data processing using GIS estimate model parameters for the numerical model. The temporal data preparation develops the boundary conditions for the model.

Basin Area

The watershed hydrology model used common practices in HSPF to define the basin area. Mass Links were defined to route water leaving the PERLND and IMPLND modules (PERO and SURO variables) to the receiving water body simulated as a RCHRES (IVOL variable). The SCHEMATIC block was then used to connect the modules as well as enter the area of each module. Some of the UCI data files showed the area was entered as a rounded integer. In all cases, the rounding was not very significant to the totals. Table 5 shows some examples of inconsistent area reporting both between basins and within a basin. For consistency, the areas in each model data file should be handled similarly and reported with consistent number of decimal accuracy. Except for the consistency issue, the definition of the basin areas followed common engineering practices.

Table 5. Area Rounding

Major Basin	Uci Name	Area Estimated to nearest:
LSJ	CL_1995.uci	1.0 Acre
LSJ	dc_cal.uci	0.1 Acre
LSJ	or_cal.uci	0.1 Acre
MSJ	Harney_aws.uci	1.0 Acre
LkG	AlexCr.uci	1.0 Acre
USJ	Usjr_main_aws.uci	0.01 Acres
OCK	Hatchetpest_cal.uci	0.1 Acres

Boundary Conditions

Both the rainfall and ET input time series were examined in the input WDM file. The rainfall and ET data for all of the models was contained in a single WDM file (RainModel.wdm). There were 142 data sets in the file. Forty six data sets were hourly precipitation, and twenty two were hourly evaporation. Each group of data was examined on an annual total basis in order to look for outliers. The rainfall input data sets are shown in Figure 1. As shown in the figure, generally, annual averages were as expected, with the exception of some low quantities (ex. FLSMERE, 2005) and occasional high outliers (ex. Clermont, 2002). These issues should be investigated further in order to determine the reasons for this discrepancy. Additionally, according to the WDM file, of the 46 hourly time series in the WDM, nine were observed, and the remainder were computed based on the nearest hourly gauge. This is a common and acceptable engineering practice when high temporal resolution rainfall data is not available.

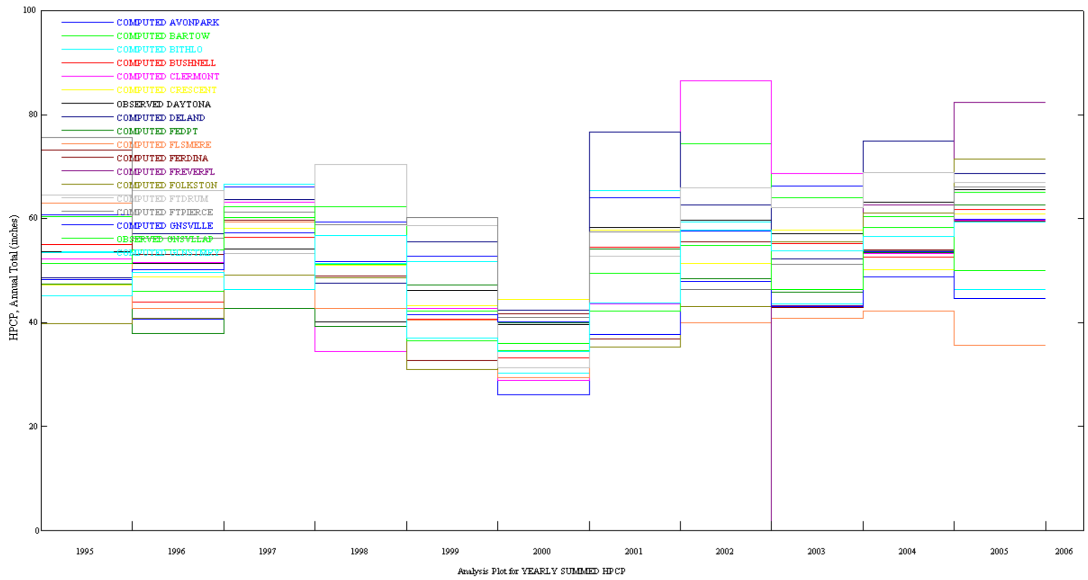


Figure 1. Rainfall Input Data Sets

Table 6. Annual Rainfall Totals by Gauge, (inches per year)

Location	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
AVONPARK	60.7	40.7	66.2	59.4	52.7	26.1	64.1	57.6	66.2	48.8	59.8	32.3	0
BARTOW	60.3	46.1	60.2	62.3	42.3	35.9	49.6	74.4	64	60.4	65	39.5	0
BITHLO	53.5	51.3	66.6	51.3	51.8	30.3	65.4	59.3	43.7	56.7	46.4	35.6	0
BUSHNELL	55	44	56.3	51.2	40.6	33.1	54.5	62.6	55.2	52.6	61.8	37.1	0
CLERMONT	52.2	51.6	63.1	**34.5**	42.7	28.9	43.5	86.4	68.7	53.3	59.6	47.1	0
CRESCENT	47.2	48.8	58.2	51	43.3	44.5	57.7	51.4	57.8	50.2	60.8	27.2	0
DAYTONA	53.6	51.4	54.2	40.2	46.3	39.7	58.3	59.7	57.1	63.1	65.6	31.1	0
DELAND	48.6	57.1	63.7	47.5	55.5	42.4	76.7	62.7	52.3	75	68.7	38.5	0
FEDPT	47.4	37.8	42.8	39.3	47.2	40	54.1	48.5	45.8	53.4	62.7	31.6	0
FLSMERE	62.9	42.7	59.3	42.8	40.4	29.4	52.7	40	40.9	42.2	35.7	29.2	0
FERDINA	73.2	53.2	59.7	48.9	32.8	41.6	36.9	55.6	42.9	54	59.6	35	0
FREVERFL	0	0	0	0	0	0	0	0	43.3	62.6	82.3	40.6	0
FOLKSTON	**39.8**	**40.9**	49.1	48.6	30.9	34.4	35.3	43.1	55.5	61	71.4	33.3	0
FTDRUM	64.6	65.3	53.3	70.5	58.6	31.3	52.7	65.9	62.2	68.9	66.9	33.7	0
FTPIERCE	75.7	56.2	61.2	58.9	60.2	41	57.5	46.3	51.2	53.8	66.1	33.8	0

GNSVILLE	48.3	50.2	57.2	51.7	41.6	40.2	37.7	48	43	53.7	44.6	31.4	0
GNSVLLAP	51.4	53.9	62.2	51.2	36.4	34.5	42.1	54.9	46.3	58.3	50	35.6	0
GLNSTMRY	45.1	49.6	46.4	56.8	37.1	34.5	43.7	57.8	53.8	56.6	59.3	39.1	0
HARTLAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
HASTINGS	55.8	57.1	66.3	57.1	46.7	44.3	54.7	52.3	58.8	60.6	65.6	31.4	0
HGHSPRGS	53.5	59.2	57.3	55.5	55.2	46.2	45.3	58.2	56.5	63.8	52.3	33.1	0
INVNESS	51.5	45.7	59.8	42.2	35.7	38.2	52.1	63.2	61	57	53.2	40.4	0
JAXAP	50.2	52.8	53.8	56.3	41.5	39.5	46.7	52.8	44.4	65.9	62.2	38.1	46
JAXB	82.8	45	59.6	42	34.7	45.8	44.6	52.6	42.4	43.6	56.6	33.7	0
KENANS	53.3	42.9	54.2	49.5	52.8	27.6	55.1	62.2	51.2	62.6	82.3	40.6	0
KISSMEE	48.7	55.8	63.5	43.3	52.2	38.1	44	69.9	56.6	58.6	71.3	36.2	0
LKALFRED	58	56	63.9	59.2	49	32	61.5	77.1	51.5	51.1	43.8	36.4	0
LKCITY	55.1	49.5	50.8	60	42.5	38.9	42.3	53.3	63.4	75.4	61.6	52.2	0
LKLAND	60.1	55.8	65	65.7	47.5	32.9	55.9	63.9	52.3	**-17900**	65.5	39.3	43.5
LEESBURG	44.4	51.8	52.3	46.2	52.1	22.2	44.4	59.9	42.6	44.7	48.2	31.3	0
LISBON	52.1	57.9	56.1	42.6	54.1	29.3	47.3	57.2	49.8	56.2	56.5	32.6	41.9
LYNNE	44.6	56.2	55.2	50.5	47.6	35.5	49.3	58.7	50.4	53.5	53.7	32.4	0
MRNELAND	47.6	46.3	63.2	42.9	38.4	41.3	51.8	51.8	43.8	46.6	55.2	32.5	0
MELB	70.3	51.4	66.4	56.2	58.3	44.3	61.4	54.9	41.9	55.6	63.2	38.7	0
MTLAKE	55.3	53.1	50.8	38	39.5	29.5	56.7	60.7	55.9	65	74.4	43.7	0
OCALA	58.1	53	49.4	53.4	45.6	28.6	45.5	58	52.4	69.8	60.4	38.2	0
OKCHOBE	58.4	43	57.5	55.8	52	25.8	53.2	**33.5**	46.1	53	57.5	30.5	0
ORLANDO	43	54.1	59.5	41.4	51.5	28.3	52.9	65.5	50.4	58.9	59.7	36	0
PALATKA	54.6	54.3	63.9	46.9	40.9	49.3	53.7	57.4	51.6	62.9	57.7	32.7	0
SANFORD	59.3	62.8	54.1	48.8	47	32.8	56.6	66.2	54.9	65.9	60.7	37.3	0
STARKE	55.6	46.5	63	38.4	41.2	34.8	42.8	57.4	61.7	59.6	52.9	38.2	0
STAUG	55.5	54.2	56.6	47	40	44.1	57.2	52.9	53.5	49.9	70	37.2	0
TITUSV	49.9	64.6	64.7	43.3	57.5	32.7	58.8	53.9	52.4	57.8	66.4	47.5	0
USHER	63.5	70.3	66.7	63.7	47	41.8	56.3	62.5	58.5	74.1	61	43	0
VERO_BCH	55.1	58.2	62	68	52.6	41.9	55.4	59.7	51.3	65.8	62.8	-3960	0
VERO_AP	47.8	59	62.2	64.8	56.1	47.3	48.9	55.9	45.4	55.7	57.4	33.6	0

In a normal year in Florida, total annual rainfall averages approximately 52 inches. Based on the annual rainfall totals from the data sets shown in Table 6, the data set development and disaggregation procedure captured total rainfall amounts fairly well. Generally, the data sets have higher rainfall totals for wet periods (1997, 1998), and lower annual totals for dry periods (2000, 2001). There were some anomalies noted in the datasets, shown in bold in the table. The Lakeland gauge experienced an extremely low rainfall total in 2004. It was suspected that this large negative value was due to ‘no data’ flags in the rainfall record. A portion of the hourly record from this gauge is shown in Table 7. As suspected, the large negative average was due to ‘no data’ flags in the hourly record. The ‘no data’ flags are acceptable to use, provided that ‘-999’ was indicated as a no data flag in the input WDM. Since GenScn is currently utilizing these values when calculating average annual rainfall, it is suspected that these are not known data flags by HSPF. If they are not recognized as no data flags, HSPF will use this value as a rainfall input. There were no problems with other datasets, so it is recommended that the rainfall WDM be modified in order to correct these entries to the time series in order to be consistent with other datasets. Based on the location of this gauge, it is possible that none of the current UCI files utilize this gauge. Nevertheless, this should be corrected in the WDM file in case this rainfall WDM is to be utilized for other modeling applications in the future.

Table 7. Lakeland Gauge Rainfall Time Series

Scenario	OBSERVED
Location	LKLAND
Constituent	HPCP
9/25/2004 21:00	0
9/25/2004 22:00	0
9/25/2004 23:00	0
9/26/2004 0:00	0
9/26/2004 1:00	0
9/26/2004 2:00	-999
9/26/2004 3:00	-999
9/26/2004 4:00	-999
9/26/2004 5:00	-999
9/26/2004 6:00	-999
9/26/2004 7:00	-999
9/26/2004 8:00	-999
9/26/2004 9:00	-999
9/26/2004 10:00	-999
9/26/2004 11:00	-999
9/26/2004 12:00	-999
9/26/2004 13:00	-999
9/26/2004 14:00	-999
9/26/2004 15:00	-999
9/26/2004 16:00	-999
9/26/2004 17:00	-999
9/26/2004 18:00	-999
9/26/2004 19:00	-999
9/26/2004 20:00	0
9/26/2004 21:00	0
9/26/2004 22:00	0
9/26/2004 23:00	0

Other observations to the total annual rainfall were as follows:

- The Folkston record shows total rainfall amounts that are consistently lower than many other gauges for any given year.
- The Clermont record is very low for 1998 (a wet year), with an annual total of 34.5 inches.
- The Okochobee record is lower than expected for 2002, with an annual total of 33.5 inches.

The twenty two hourly ET records are shown in Figure 2. It should be noted that correction factors are applied to this data when it is read in the External Sources block. The JAXB record is low, averaging approximately 46 inches per year (before the correction factor is applied). This data set should not be utilized (DSN 2806) without further explanation or correction for the low ET estimation. Additionally, the correction factors that are applied to each model should be noted in the report documentation. If individual factors for each basin are not provided in the documentation, then the range of the factors should be provided. Figure 3 shows the ET data sets used for the Lake Jesup model (jesup_aws_1.uci). For this particular model, the data is consistent with common engineering expectation for annual ET total.

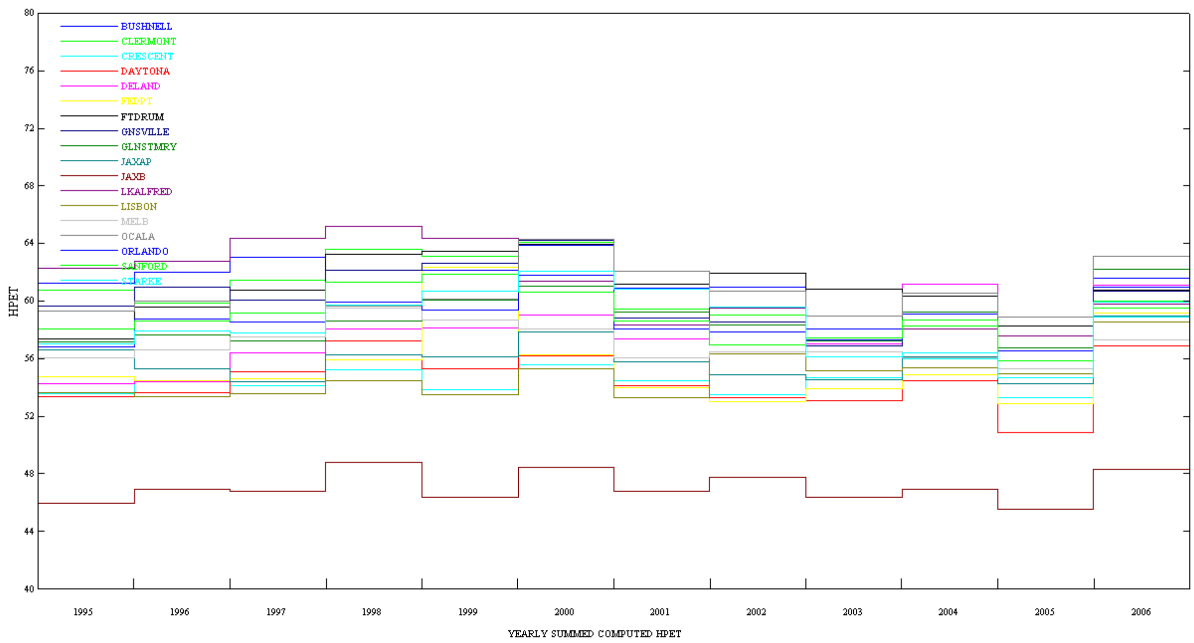


Figure 2. Input ET Annual Totals (inches)

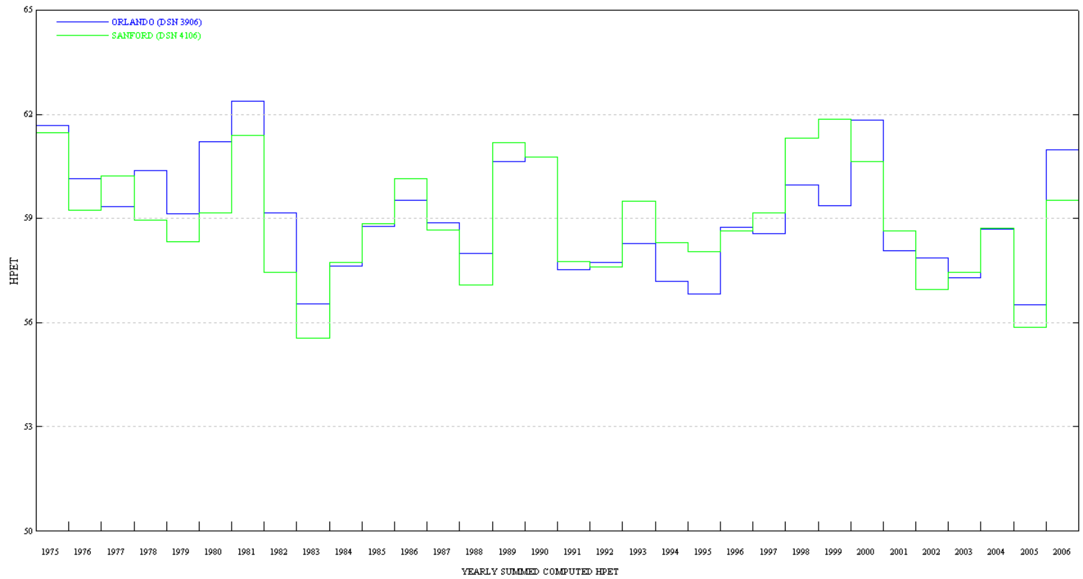


Figure 3. Annual ET Totals (DSNs 3906 and 4106 as referenced in jesup_aws_1.uci)

Initial Conditions

There were some irregularities related to the definition of the model initial conditions. The initial conditions define the magnitude of the storages at the beginning of the simulation. Even though these are the initial conditions they can have an impact on the model results for several months into the simulation. To determine the impacts, the storage variables can be plotted with time. Plotting the data can show the transient nature of the storages introduced by the initial condition as well and enable a rough estimate of how long the instabilities impact the simulated results. In the watershed hydrology model, some of the model data sets show several important initial storages were defined without concern as to the impacts of the simulated results. Variables that are slow to stabilize are Lower Zone Storage (LZS) and Active Groundwater Storage (AGWS). The degree and duration of the stabilities are controlled by many factors, including the precipitation quantity near the beginning of the simulation, infiltration parameters, and relative magnitude of the parameters as well as the transient. Incorrectly defining these storages can adversely impact the simulated results for several months (as shown in the graphics, up to 9 months).

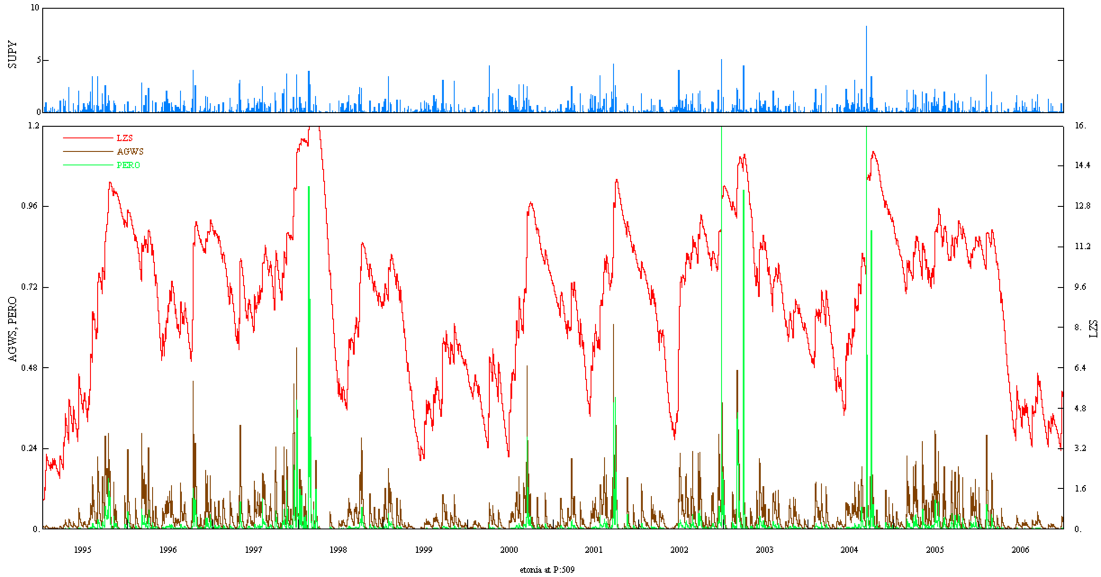


Figure 4. Etonia, PERLND 509 (Land Use: Agriculture Tree Crops), Entire Simulation Period

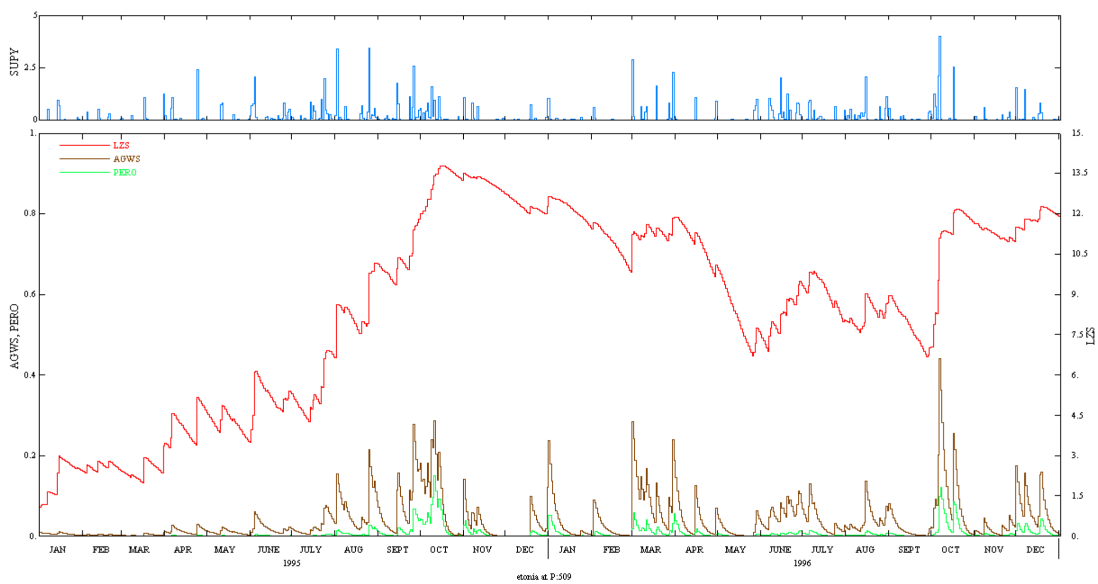


Figure 5. Etonia, PERLND 509 (Land Use: Agriculture Tree Crops), 1995-1996.

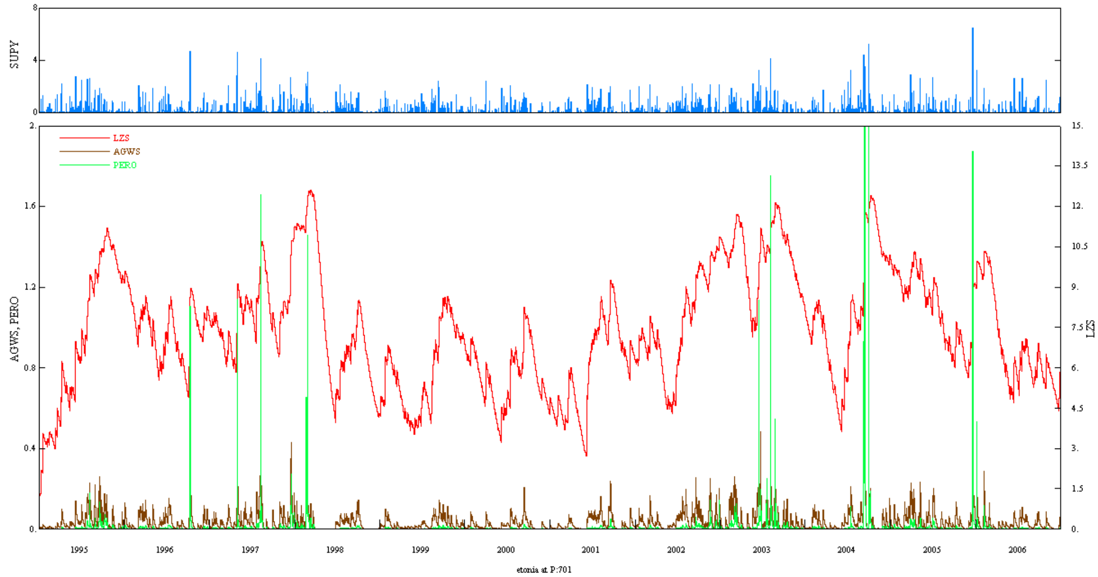


Figure 6. Etonia, PERLND 701 (Land Use: Low Density Residential), Entire Simulation Period

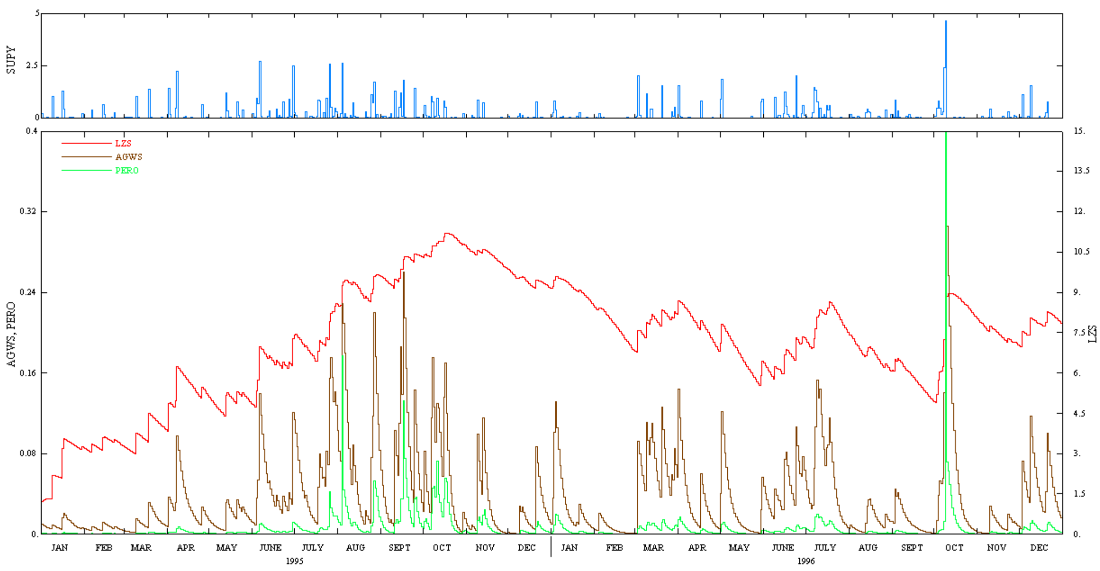


Figure 7. Etonia, PERLND 701 (Land Use: Low Density Residential), 1995-1996

The LZS of a basin should be defined at approximately the Lower Zone Nominal Storage (LZSN). This will result in a Lower Zone Ratio (LZRAT) of 1.0. The model naturally gravitates to a LZRAT of 1.0 since the inflow quantity is controlled by the ratio. If the ratio is less than 1.0, more water enters the lower zone; if the ratio is greater than 1, the water that enters the lower zone is reduced. If the initial LZS is defined such that the ratio is significantly different than 1.0, the model will have a transient condition that might take some time to diffuse out of the system, as shown in the figures. If the antecedent conditions show the system is either in a wet or dry state then the initial LZS should reflect the correct condition.

As stated earlier, the model should not have storages that have to recover from initializing storages outside what would be considered a valid condition given the antecedent conditions. If the model is initialized incorrectly, then an easy correction is to discard the first year from the model comparison with the observed data. This will prevent the invalid data from adversely affecting parameter calibration given the poor agreement due to the invalid initialization.

Special Actions

Lake Leakage

Baseflow in HSPF is represented only as an outflow from basins or the PERLND module. The HSPF baseflow flux only represents fluxes that enter water bodies from the shallow aquifer only; it does not represent the deep aquifer exchanges. The Active GroundWater Outflow (AGWO) or HSPF baseflow flux can enter the water bodies that are represented with RCHRES modules. The RCHRES module, without special actions, does not interact with the aquifer and, as previously mentioned, can only receive shallow aquifer outflow (HSPF can not simulate losses). In Florida, significant fluxes into and more importantly, out of water bodies can be present. The lack of aquifer interaction would impact the model performance and its ability to represent the processes present in the St Johns River Watershed. Therefore, it was essential for the District to represent the lake losses as a special action to account for the significant water budget term.

For the 2030, scenario it might be best to use a time series representing the aquifer heads that was generated from the District's groundwater model. Future conditions should take future water levels (based on future groundwater withdrawals) into account.

Area Correction

In standard HSPF, the areas of reaches change with the relationship defined in the F-Table. The F-Table defines the non-linear relationship of stage, storage, area, and discharge of the RCHRES. The changing area in the reach should be offset with changes in the associated basin area. Unfortunately, HSPF is incapable of automatically changing the basin area. The District has applied correction to some of the reach areas to account for the inherent mass balance error.

Unfortunately, the area correction was not performed on all reaches. Reaches were allowed to change in area without correcting the mass balance of the overall watershed. For example, as shown in Table 8, Reach 13 of the 04msjr_a_econ3 simulation was allowed to vary from 15 acres to over 700 acres with no correction. That amount of fluctuation would introduce mass balance error in the overall simulation results. When the area is larger than the mapped area, it would create mass when it rains. When the area is less than the mapped area, it would destroy mass when it rains. The table below shows the differences in the reach area between the maximum and minimum simulated area for the calibration. As shown in the table, the difference is on the order of many square miles.

Table 8. Reach Areas, econ_aws.uci

ReachID	Maximum	Minimum	Mean	Difference between max and min
R:1	1640	598	879	1042
R:2	340	1.7	18.6	338.3
R:3	128	0.7	7.2	127.3
R:4	115	1.5	9.5	113.5
R:5	122	4	18.2	118
R:6	594	7.3	41.2	586.7
R:7	75.5	0.6	6.9	74.9
R:8	923	16.2	70.1	906.8
R:11	582	4	84	578
R:111	315	2.1	30.7	312.9
R:12	717	546	594	171
R:112	615	122	562	493
R:13	733	15	61.6	718
R:113	373	8.5	29.7	364.5
R:9	1120	872	1000	248
R:10	3990	135	242	3855
R:110	1950	56.6	96.7	1893.4

Structure Flux and Pump Control

There are many complex control structures within the St John River Watershed. These structures help regulate the flow of water within the watershed. The flow in these structures was computed with complex special action routines. These routines take into account the control geometry, upstream and downstream stages, and seasonality. Pumps in the watershed are also computed in the special actions block. Pumps are used to move water within the watershed. The control of these pump are stage triggers. As the stages in the reaches hit the triggers, the pumps are controlled.

Lakes and Wetlands as PERLND

Typical HSPF model applications have represented lakes and wetlands with either PERLND modules or RCHRES modules. There are advantages and disadvantages to either technique. Essentially, PERLND modules assume water is infiltrating based on the Lower Zone Storage (LZS). The RCHRES module becomes difficult to calibrate because discharge and storage are dependant on the user defined F-Table.

The current SJR watershed hydrology model used PERLND modules to simulate open water and wetlands within the basins. The PERLND module in HSPF was designed to represent PERvious LaND segments. It can, however, be used to represent wetlands.

Model Calibration

As with development of all models, calibration is a very important and time consuming step in the model development process. Calibration is the adjustment of the model parameters to improve the fit of the model as compared to observed fluxes and events. A good calibration matches the observed storages and fluxes while maintaining the parameters within reasonable or literature ranges.

Along with matching the observed fluxes, model calibration should also take into account fluxes and storages that are not observed. The model simulation should match reasonable or literature range recharge rates. During long term simulations, storages, such as reach volumes, should not continue to increase or decrease (unless a trend is noted in the meteorological conditions). In addition, most simulated storages (excluding interception storage) should not be reduced to zero on a regular basis. Examples of these simulated storages include reach storages and Lower Zone Storage (LZS). If the simulated storages are reduced to zero, then associated ET fluxes will be unrealistically zero.

ET is a significant component of the hydrologic cycle. The direct measurement of ET is very rare and only recently was it even possible. Given the significance of ET to the hydrologic water budget of a basin, ET should be an objective function to achieve reasonable rates. Open water areas should achieve potential ET.

HSPF has the capability to simulate a wide variety of physical processes. This capability can enable replication the outflow hydrograph in many ways. For example, attenuation in the outflow hydrograph can be accounted in the model as storage in a RCHRES or using interflow storage (IFWS). While the attenuation process can be replicated using different techniques, other components of the water balance will be affected differently. Interflow storage does not allow ET losses. If InterFloW Storage (IFWS) is used to attenuate flows, the storage would not allow ET to be removed, thus impacting the overall water budget.

PEST Calibration

All models were calibrated using Parameter ESTimation (PEST). Initial parameters were established by comparing the watershed to a nearby watershed or to common values. Parameters adjusted by PERT included LZSN, LZEPT, INFILT, UZSN, AGWRC, INTFW, IRC, and DEEPFR. In order to ensure that the final parameter set remained constant, parameter upper and lower bounds are defined. After a calibration simulation is run, PEST adjusts parameters to minimize the weighted residual error of objective functions. The objective functions utilized for the watershed hydrology model calibrations were as follows (Volume 1):

- Average Daily Flow
- Average Monthly Flow
- Average Annual Flow
- Flow Duration Curve

PEST calibration was consistent with common engineering practices.

Water Balance Calibration

Simulated TAET

HSPF simulates the total actual ET (TAET) based on the user defined parameters and the available moisture. TAET is the second largest water budget term of the watershed. TAET for each land use is shown in Figure 8.

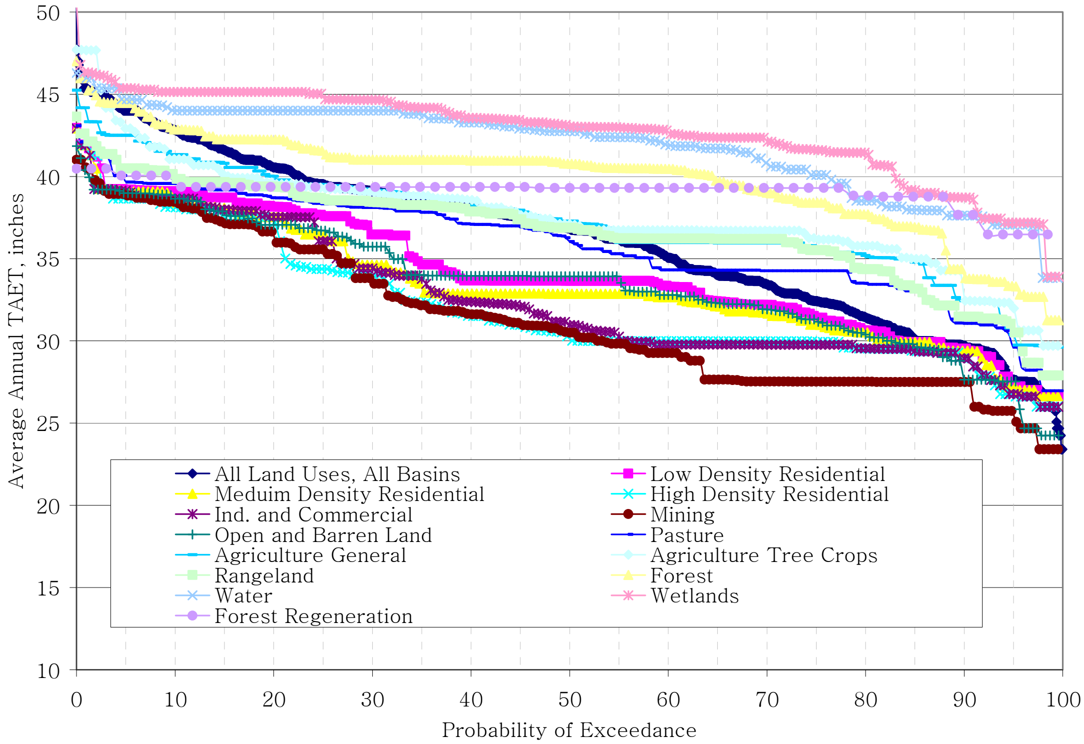


Figure 8. Simulated TAET

Simulated Pervious Runoff

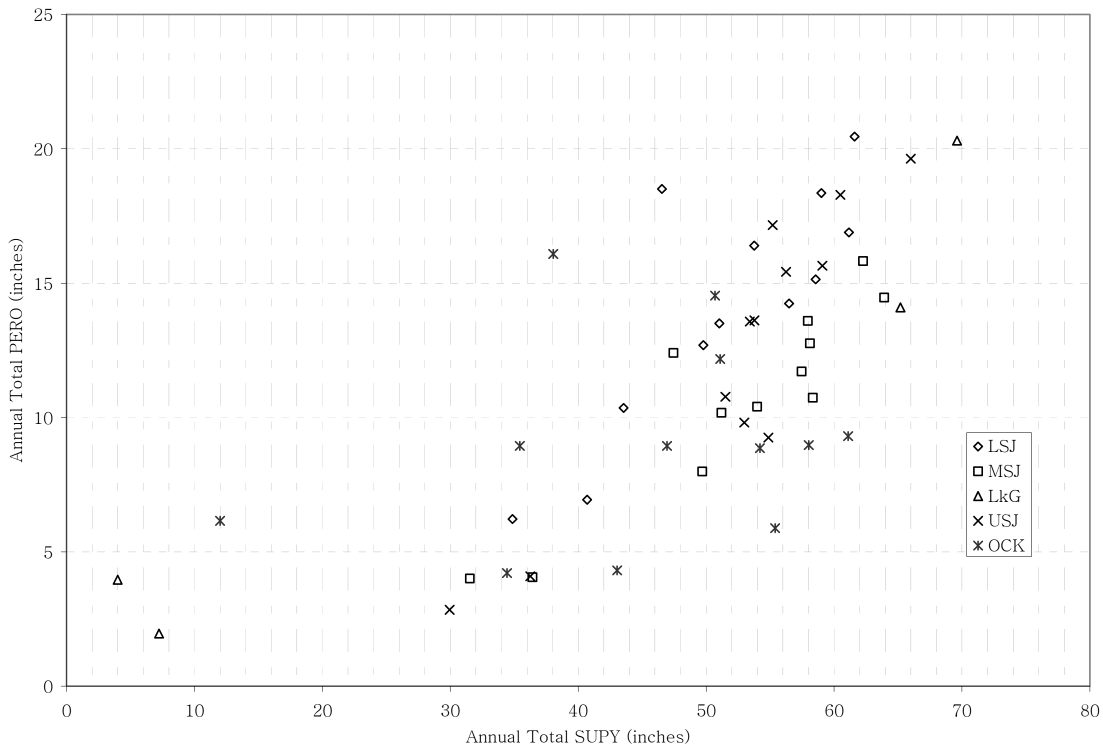


Figure 9. Total PERO by Basin (PERO2_Budget_query5.xls)

Simulated Impervious Runoff

A water balance summary for the 4 impervious land use types is shown in Table 9. As shown in the table, the water balance was fairy consistent across all impervious land uses, with an average of 42.75 inches of runoff (SURO) generated for each impervious land segment. (Note that the values shown in the table are **not** area weighted based on the area of each IMPLND, but rather simple averages of all IMPLNDs for each segment.) This simulated impervious runoff is slightly high, particularly considering the high DCIA percentages for some of the land uses. The very small RETS indicates that there is a very small amount of retention storage for each impervious segment. RETSC, the retention storage, would commonly be utilized to represent surface detentions in impervious land segments, such as pore space and depressions in parking lots, as well as other retention storage, such as retention ponds to which impervious areas drain. The amount of retention storage allotted for any given IMPLND is specified by RETSC in the UCI. Table 10 shows RETSC values for several UCIs. As shown in the table, these values are fairly low; although these values may account for pore spaces in impervious areas such as asphalt parking lots and pavements, these small values are not significant enough to account for retention storage, such as retention ponds.

Table 9. Average Implnd Water Balance by Land Use

	1	**2**	**3**	**4**	**Average**
SUPY	50.78	50.31	50.20	50.49	50.44
SURO	-43.12	-42.62	-42.49	-42.78	-42.75
IMPEV	-7.66	-7.70	-7.71	-7.71	-7.69
RETS	0.01	0.01	0.01	0.01	0.01

Table 10. Retention Storage Capacity

Basin	Model UCI	RETSC (inches)
Lake George	AlexCr_cal.uci	0.07
Lower St. Johns	bc_cal.uci	0.05
Middle St. Johns	econ_aws.uci	0.05
Upper St. Johns	6a_ftdrum_aws.uci	0.05
Ocklawaha	LHatchet_cal.uci	0.07

As simple sensitivity analysis was conducted to examine the model sensitivity to RETSC. The Little Hatchet Creek model was run with the original RESTC value of 0.07 inches for all IMPLND segments. RETSC was then changed to 0.25 inches, a value which is slightly higher and accounts for more detention storage. Table 11 and Figure 10 show the change in average surface runoff from the change in RETSC for impervious segment 261.

Table 11. Change in Runoff with RETSC

RETSC (in.) Location Constituent Mean	**0.07** I:261 **SURO** 40.6	**0.25** I:261 **SURO** 32.6
1995	44.7	36.5
1996	46.7	38.7
1997	54.3	44.9
1998	44.3	37.1
1999	28.7	20.9
2000	27.6	21

2001	34.7	27.5
2002	45.6	36.1
2003	37.6	28.8
2004	50.8	43.2
2005	41.7	32.7
2006	30	24.1

Newer developments have retention storage that should be taken into account either through an increase in RETSC or through the use of storage attenuation reaches. The use of a higher RETSC results in a more realistic annual total runoff and could result in more realistic predictive analyses.

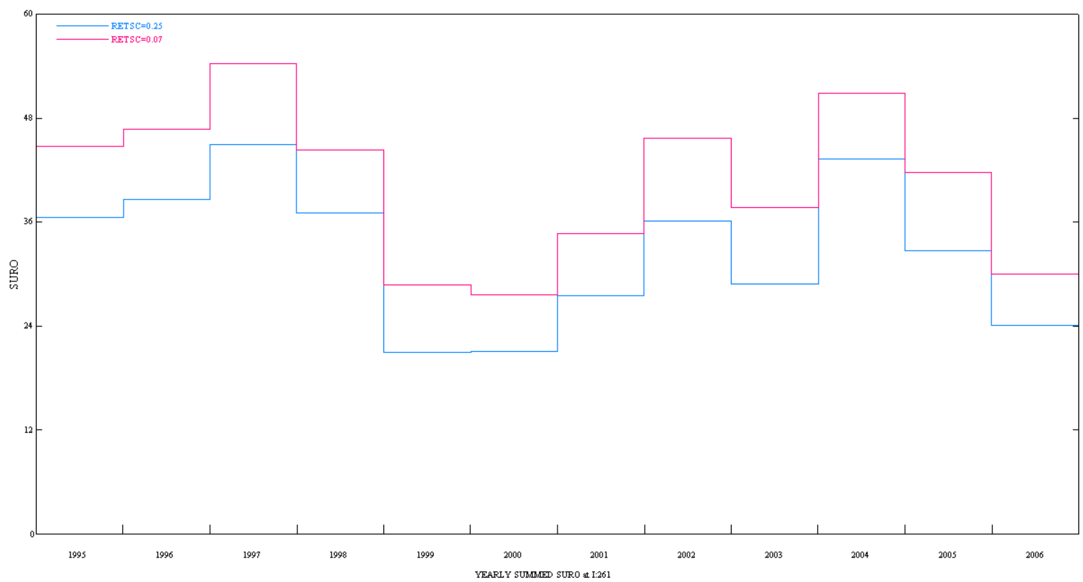


Figure 10. Little Hatchet Creek, SURO Comparison, IMPLND 261

Interflow

By definition, interflow is the lateral movement and ultimate discharge of infiltrated water within the vadose zone or before the water enters the saturated aquifer. In Florida, the vadose zone or depth to the water table is so thin and the slopes are so shallow it can not support a significant interflow flux. However, the interflow storage and interflow outflow can be used to attenuate the runoff from a basin. In order the use the inflow process as a mechanism to attenuate the basin discharge, other model water balance terms need to be adjusted to adapt the interflow process into an attenuation process.

Interflow storage in HSPF does not have the capability to evaporate. In the natural system, the storage within the basin is always available to satisfy potential ET. When interflow storage is used to attenuate runoff, the ET will have to be double accounted for in other processes.

In the natural system, stormwater runs off the upland landforms. This runoff will eventually enter the wetlands, lakes, and rivers. The wetlands, which are prevalent in the Florida landscape, can provide significant storage capacity. This storage capacity can impact the shape of the runoff hydrograph as well as the total volume. Storage in the natural systems can occur below an invert, meaning at low stages water can enter the receiving water bodies, but because of a natural sill, will not be able to discharge. In contrast, the interflow storage can discharge all the way to zero. Storage below an invert is incapable of discharge to the downstream system. HSPF can not replicate the storage without discharge process using the interflow storage technique.

Active Groundwater and Inactive Groundwater

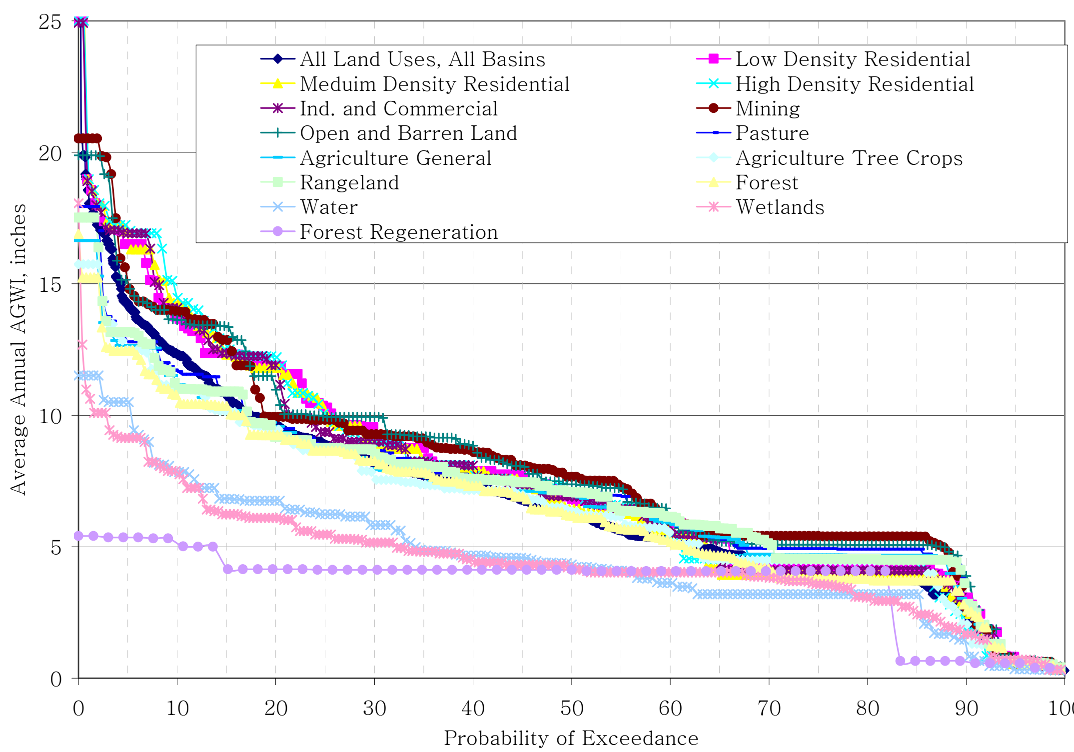
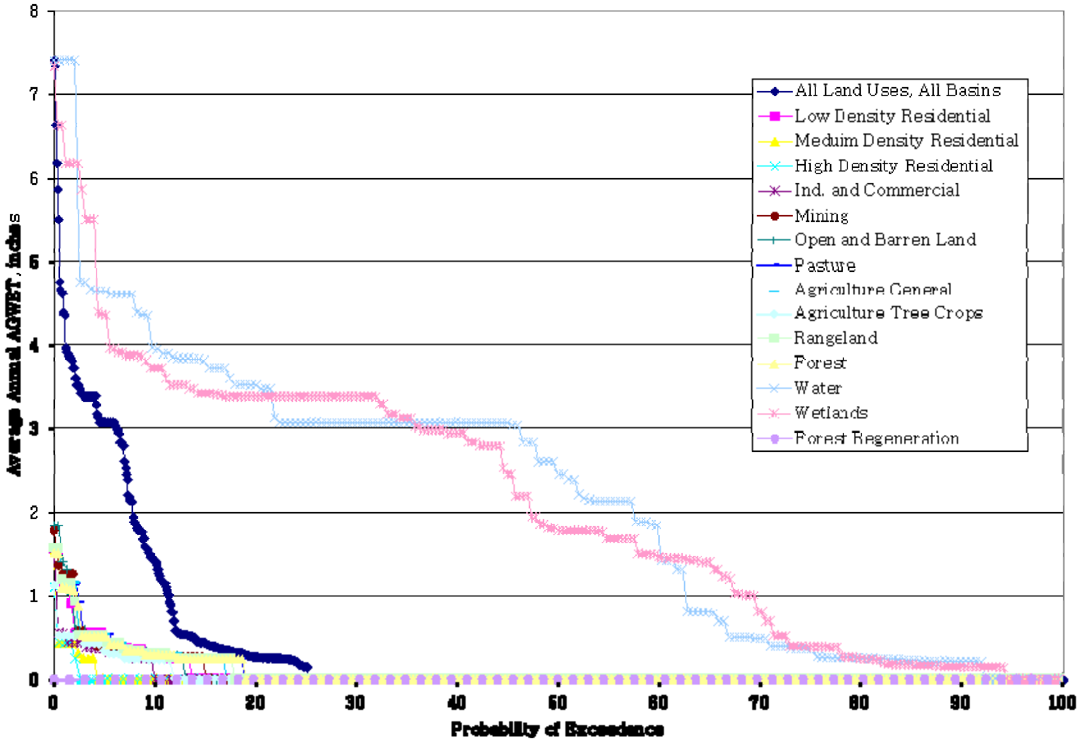


Figure 11. Average AGWI, inches

Table 12. Average AGWI by Land Use

Land Use	Min	Max	50^{th} percentile
1	0.36	25.00	6.80
2	0.33	26.51	6.43
3	0.37	25.00	6.98
4	0.33	24.92	6.92
5	0.44	20.52	7.66
6	0.45	19.89	7.37
7	0.44	17.94	7.10
8	0.43	16.64	6.97
9	0.41	15.74	6.36
10	0.41	17.51	7.08
11	0.37	16.90	6.16
12	0.29	11.51	4.33
13	0.32	18.05	4.19
14	0.39	5.41	4.12
All Land Uses	0.29	26.51	6.23



Average Annual AGWET, inches
Probability of Exceedance
All Land Uses, All Basins
Low Density Residential
Meduim Density Residential
High Density Residential
Ind. and Commercial
Mining
Open and Barren Land
Pasture
Agriculture General
Agriculture Tree Crops
Rangeland
Forest
Water
Wetlands
Forest Regeneration

Overall Water Balance

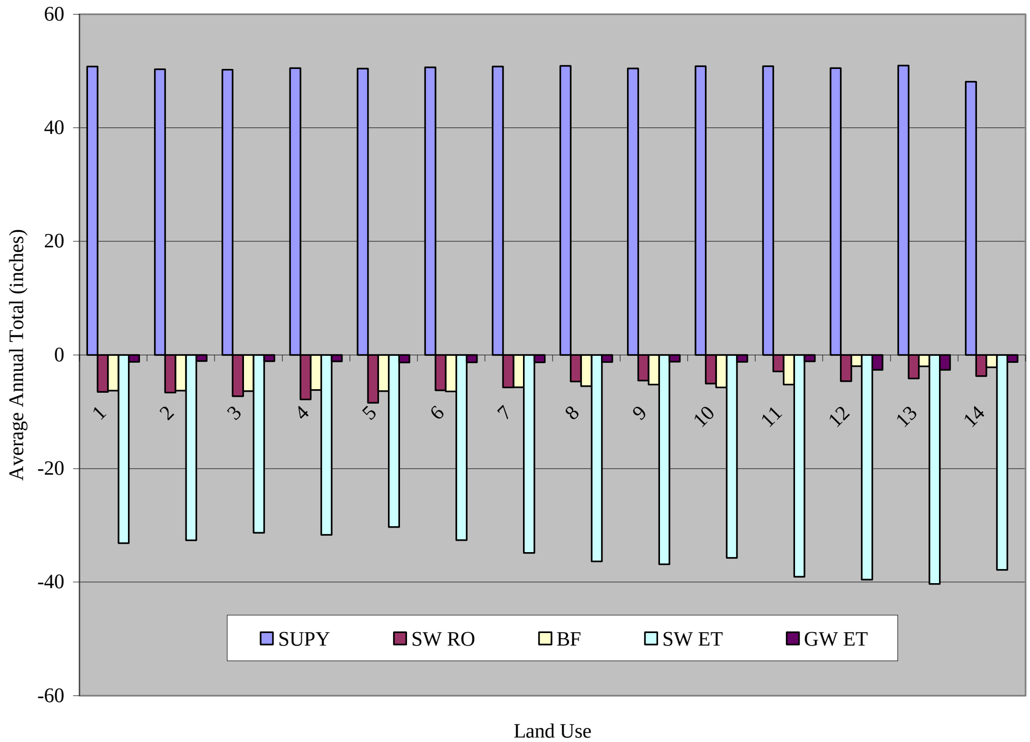


Figure 12. (Avg_Budget_by_LU_Perlnd_Crosstab.xls)

Table 13. Average Annual Perlnd Water Balance by Land Use (inches)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Avg.
SUPY	50.8	50.3	50.2	50.5	50.4	50.6	50.8	50.9	50.5	50.8	50.8	50.5	50.9	48.1	50.4
SW RO	-6.5	-6.6	-7.3	-7.8	-8.4	-6.2	-5.7	-4.7	-4.5	-5.0	-2.9	-4.6	-4.1	-3.7	-5.6
BF	-6.3	-6.3	-6.4	-6.2	-6.3	-6.4	-5.7	-5.5	-5.2	-5.7	-5.2	-2.0	-2.0	-2.2	-5.1
SWET	-33.1	-32.6	-31.3	-31.7	-30.3	-32.6	-34.9	-36.3	-36.8	-35.7	-39.1	-39.6	-40.3	-37.9	-35.2
GWET	-1.2	-1.1	-1.1	-1.1	-1.3	-1.3	-1.3	-1.2	-1.2	-1.2	-1.1	-2.6	-2.6	-1.2	-1.4

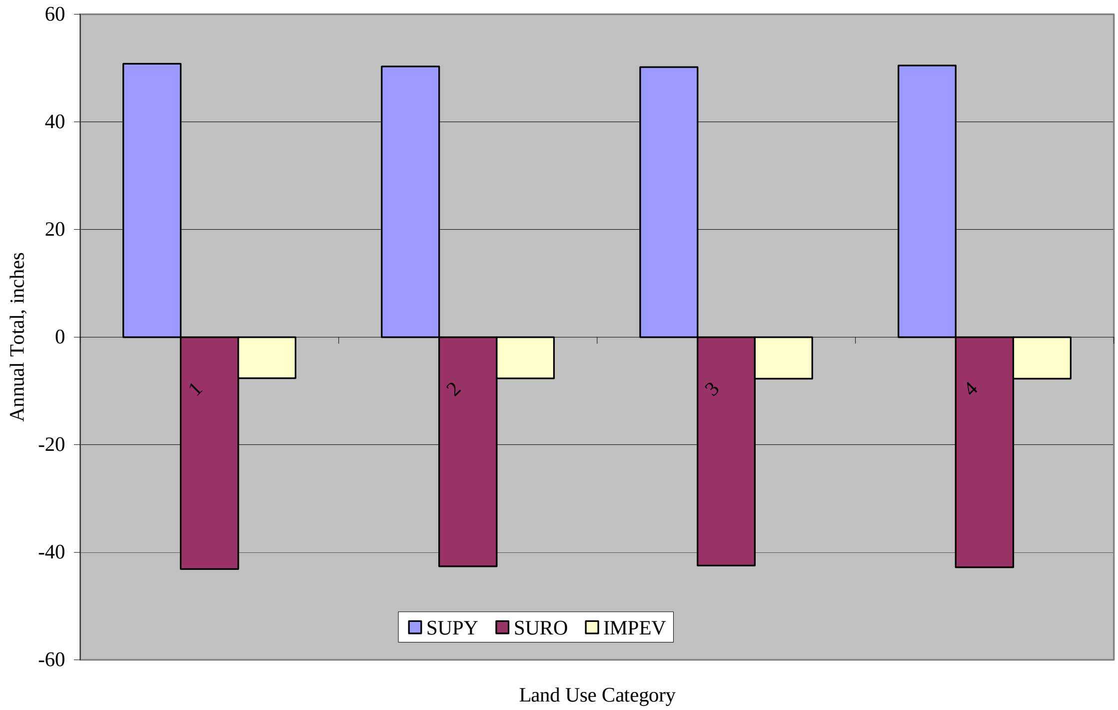


Figure 13. Avg. Annual Implnd Water Balance by Land Use (Avg_Budget_by_LU_Implnd_Crosstab.xls)

Table 14. Average Annual Implnd Water Balance by Land Use (inches)

	1	2	3	4	Average
SUPY	50.78	50.31	50.20	50.49	50.44
SURO	-43.12	-42.62	-42.49	-42.78	-42.75
IMPEV	-7.66	-7.70	-7.71	-7.71	-7.69
RETS	0.01	0.01	0.01	0.01	0.01

Streamflow Calibration

Review of streamflow calibration should focus on whether or not the models met statistical targets in comparing observed and simulated flows and stages in streams and lakes. A good match between observed and simulated flows is an integral portion of a well calibrated model, provided that the parameterization producing the flows is realistic. The model documentation provided a plethora of useful statistics in order to evaluate the model performance. Statistics were those recommended by the District in a prior technical publication for HSPF modeling. (Citation) Nash-Sutcliffe Efficiency (NSE) statistics were provided for each of the models. A NSE of one indicates that the model is a perfect match to observed data, while a NSE of zero indicates that the mean value is a better predictor of observed data than the model. Of the fifty-one models presented, eight had calculated NSEs of less than 0.5. Statistics for those models are shown in Table 15.

Table 15. Selected Model Statistics

Model	NSE	Mean Daily Flow, cfs		Maximum Daily Flow, cfs	
		Obs.	Sim.	Obs.	Sim.
03lsjr_h_JC_BigDavis	0.47				
04msjr_c_econ1	0.20	28.74	30.59	391.0	538.91
04msjr_c_jesup3	0.49	16.69	17.78	262.0	303.37
04msjr_e_litwek_AltSprngs	0.38	84.15	99.92	648.0	1298.67
06usjr_b_s-96c	0.37	202.8	221.95	1890.0	1500.0
06usjr_c_s-96b	0.34	142.65	144.6	1717.0	1000.0
06usjr_e_crabgrass	0.29	27.16	28.12	1158.14	2574.57
06usjr_g_taylor	0.39	51.79	50.9	1110.0	1033.37

Accurate estimation of mean daily flow is an indicator that the model is accurately simulating the overall discharge volume. Overestimation of mean daily flow (as shown in the table) indicates that the model is overestimating the volume of water in a given reach. Depending on the ultimate purpose of the model, this can be a very important point that should not be overlooked, particularly for water use planning purposes. Figures 14 and 15 show the daily and monthly hydrographs (respectively) for the S-96C model. As shown in the figures, as the time step increases from daily to monthly, the difference in volume (ie. The difference between the areas beneath the simulated and observed hydrographs) can be compared more easily. If the ultimate purpose of a model is to determine the amount of water available for public supply, then great care should be taken model the mean daily flow (and therefore total flow volume) as accurately as possible.

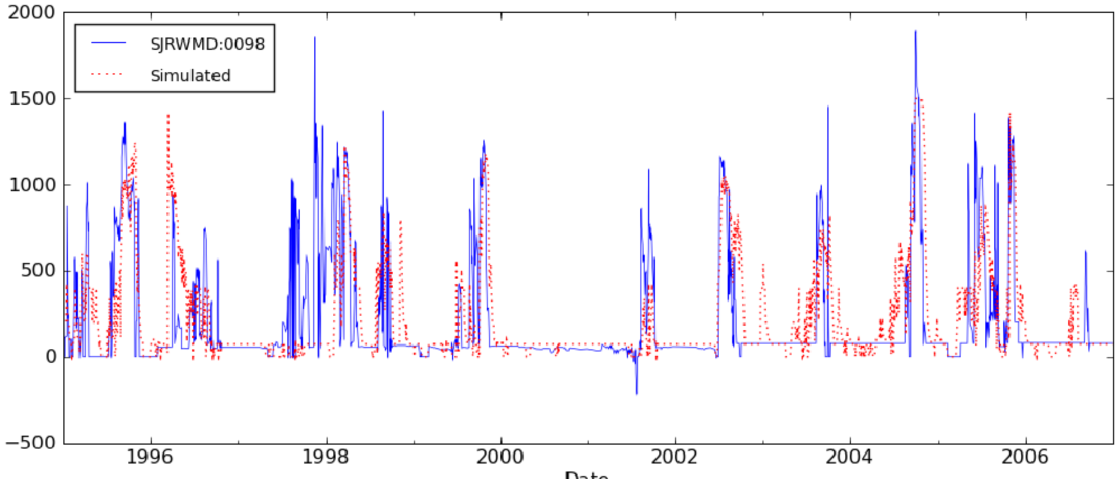


Figure 14. S-96C Daily Hydrograph (06usjr_b_s-96c). Source: Volume 2

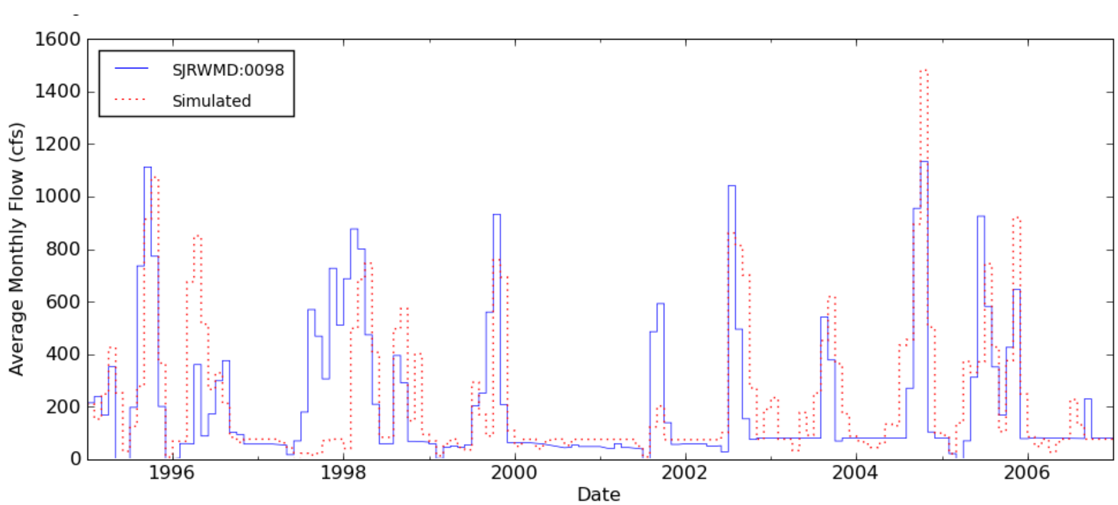


Figure 15. S-96C Monthly Hydrograph (06usjr_b_s-96c). Source: Volume 2

Similarly, accurate estimation of maximum daily flow is an indicator of how well the model is representing the attenuation in a given reach. In many cases, the models overestimated the maximum daily flow, at times by over 100-percent (ex. Crabgrass Creek). Figure 16 shows the daily flow hydrograph and rainfall input for Crabgrass Creek. As shown in the figure, there is a significant rainfall event at the beginning of the simulation which results in a high simulated discharge a short time later. The observed discharge, however, does not show this same peak. While this model represents the mean fairly well (27.16 cfs observed versus 28.12 cfs simulated), flow attenuation is not represented well. This is a temporal issue which could be alleviated by routing flows through a storage attenuation reach. The Econlockhatchee River at Magnolia Ranch model, shown in Figure 17, also has similar attenuation issues. This lack of flow attenuation results in an overestimation of stormwater and an underestimation in baseflow. In some cases, this could be land use driven, making it even more vital to exercise caution when utilizing the model for predictive purposes and modifying land uses.

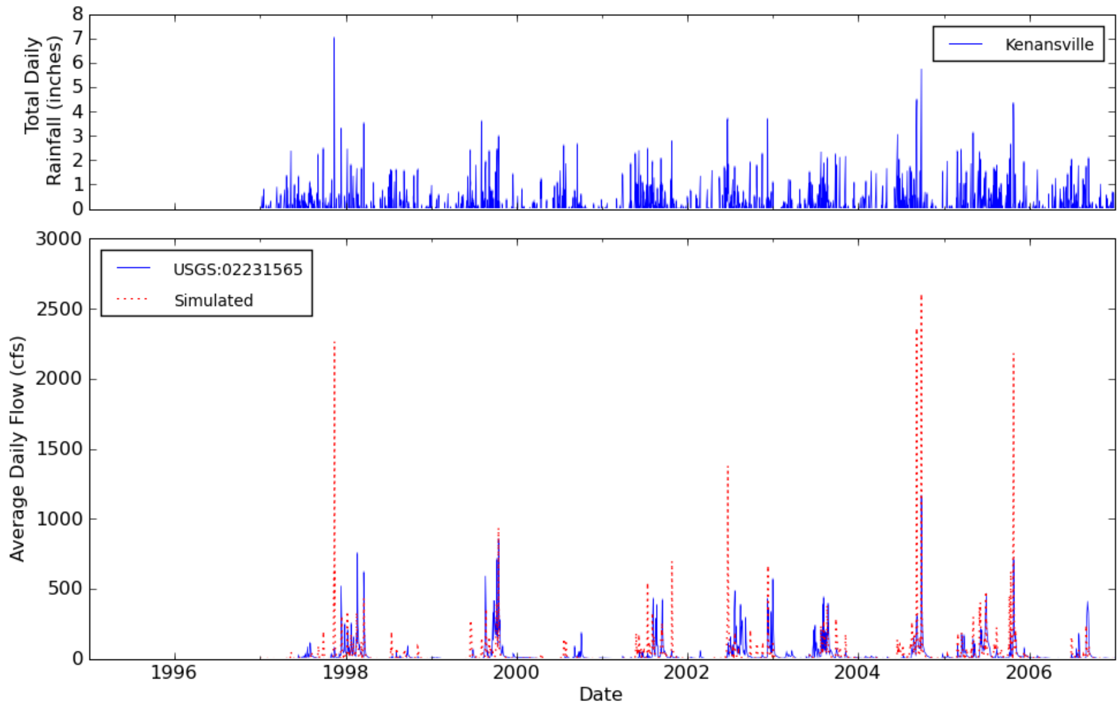


Figure 16. Crabgrass Creek Daily Hydrograph and Rainfall (06usjr_e_crabgrass) Source: Volume 2

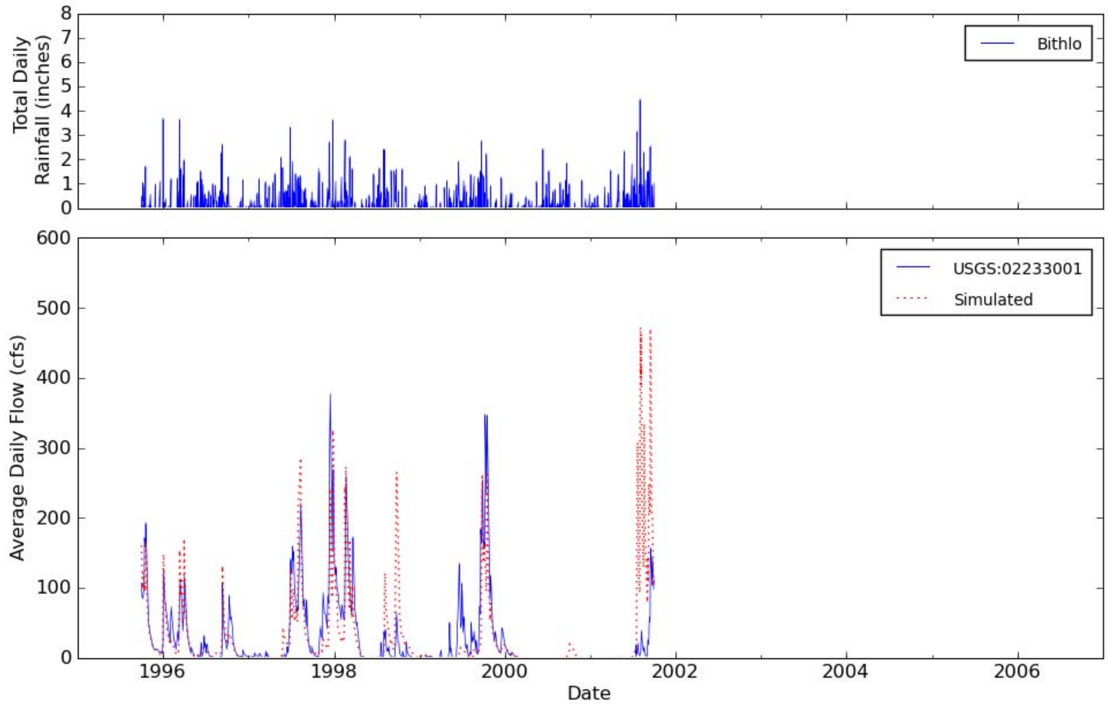


Figure 17. 2: Econlockhatchee River at Magnolia Ranch Daily Hydrograph (04msjr_econ1) Source: Volume 3

Errata

The table below lists the significant errors found in the report and appendices. These errors need to be addressed along with a proof read of the report.

Volume	Page	Description
1	12	Assumed note to author should be deleted. Blank page unnecessary
1	12	Figure 1 repeated.
1	43	Appendix reports water as 100% impervious. Should be 0%.
1	30	Extra caption for figure 8 should be deleted.
1	26	Figure caption in text.

References

EPA. (July 2000). *BASINS Technical Note 6: Estimating Hydrology and Hydraulic Parameters for HSPF*. EPA.

GIS Associates, Inc. (2009). *Projection of Land Use Change from 1995 to 2030 By Watershed for the SJRWMD.* Contract SK305RA, Work Order Number 21. Palatka, FL: St. Johns River Water Management District.

GIS Associates, Inc. (2009). *SJ2009-SP7: The Small Area Population and Distribution Methodology of the St. Johns River Water Management District for the 2008 District 'Water Supply Assessment' and the 2010 District 'Water Supply Plan'.* Palatka, FL: St. Johns River Water Management District.

USJ Review

Alley and Veenhuis, 1983

Lake Jesup Review

Robison, Lake Hiawassee Model

WSIS, Vols 1-5